UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

MEMORANDUM

SUBJECT: Review of Benefits for Sulfoxaflor for Fruiting Vegetables, Cucurbit Vegetables, Citrus, and Cotton. (DP# 384640)

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Product Review Panel date: November 19, 2012

SUMMARY and CONCLUSIONS

Dow AgroSciences submitted an application for a Section 3 Registration for the new insecticide sulfoxaflor. BEAD has reviewed efficacy of alternative insecticides for four crop groups: fruiting vegetables, cucurbit vegetables, citrus, and cotton. Due to ongoing concerns for honey bees, the review also assesses the importance of commercial honey bees as crop pollinators for the assessed crop groups.

Based on submitted and readily available efficacy information, BEAD concludes that sulfoxaflor will play an important role in pest management on these crops. Due to its unique chemistry and lack of cross-resistance to the neonicotinoid class insecticides, sulfoxaflor should be a valuable tool in pesticide resistance management. Furthermore, while honey bees play an important role as pollinators in the crop groups examined, growers should be able to time the application of sulfoxaflor as to result in minimal exposure to honeybees.

INTRODUCTION AND BACKGROUND

Dow AgroSciences has submitted an application to the Registration Division (RD) of the Office Pesticide Programs Chemical Safety and Pollution Prevention of the EPA for a Section 3 registration of the insecticide sulfoxaflor for use on cotton, soybean, cereals, citrus, leafy and fruiting vegetables, grapes, cole crops, and apples. Sulfoxaflor has been registered for use on cotton in the mid-south production region under a Section 18 emergency exemption to control tarnished plant bug since 2012. Due to potential risks to honey bees, BEAD was requested by RD to conduct an assessment on four of the crop groups (fruiting vegetables, cucurbit vegetables, citrus, and cotton) to determine benefits which would be associated with the registration of sulfoxaflor. As part of this assessment BEAD also examines the importance of honey bees in the production of each of the assessed crop groups.

General Information About Sulfoxaflor

Sulfoxaflor (XDE-208) is a new insecticide which targets a broad spectrum of piercing/sucking insects including aphids, plant bugs, whiteflies, planthoppers, mealybugs, and scales. Sulfoxaflor is the first member of a new class of insecticides, the sulfoximines. The sulfoximines act through a unique interaction with the nicotinic acetylcholine receptor in insects. Similar to neonicotinoids, sulfoxaflor is a highly efficacious agonist of the nicotinic receptor with low affinity for the imidacloprid binding site. The structure of sulfoxaflor makes it stable in the presence of a monooxygenase enzyme that was shown to degrade a variety of neonicotinoids. This stability results in broad lack of cross-resistance to neonicotinoids and other insecticide families. Sulfoxaflor acts through both contact and ingestion and provides both knockdown and residual control.

Scope of the Assessment: Data used for this assessment consisted of USDA data (Agricultural Chemical Usage, Agricultural Statistics, Census of Agriculture, Crop Profiles, and Pest Management Strategic Plans), state insecticide recommendations, California Pesticide Use Reporting (CPUR), publically available documents/efficacy studies, and EPA proprietary use/usage data. Insect pests were not considered in the assessment if the proposed labeling indicated that sulfoxaflor will only provide suppression rather than control.

BENEFIT ASSESSMENTS

Crop Production in the United States

Based on available crop acreage data in 2007 (USDA/NASS 2009), fruiting vegetables were grown on approximately 550,400 acres, cucurbit vegetables on 539,400 acres, citrus on 1,004,500 acres, and cotton on 10,493,200 acres. Table 1 provides the acreage for each available crop for the designated crop groups.

Table 1. Crop Production by Crop Group in the United States.

Crop Group	Crop	Acres in U.S.
Fruiting Vegetables and Okra	Eggplant	6,038
	Okra	2,444
	Peppers, Bell	62,363
	Peppers, Other	37,372
	Tomatoes	442,225
Cucurbit Vegetables	Cantaloupe	84,290
	Cucumbers	151,759
	Honeydew Melons	13,573
	Pumpkins	92,955
	Squash	54,454
	Watermelons	142,359
Citrus	Grapefruit	102,578
	Lemons	66,972
	Limes	1,251
	Oranges	785,856
	Tangelos	9,694
	Tangerines	36,965
	Temples	1,211
Cotton	Cotton	10,493,238

Source: USDA/NASS 2007 Census of Agriculture

Cotton production accounts for 83.4 % of the total acreage which could potentially be treated with sulfoxaflor. Based on acres produced information, the assessment will be directed towards the following representative crops for each crop group; fruiting vegetables (tomatoes and pepper), cucurbit vegetables (watermelons, cucumbers, pumpkins, cantaloupe, and squash), citrus (oranges and grapefruit), and cotton.

<u>Fruiting Vegetables</u>

Limitations for Fruiting Vegetables: This analysis is limited to insecticide use on tomatoes and peppers. These crops were chosen as they represent most acreage in the fruiting vegetable crop group.

Label Pest(s): Aphids, plant bugs, greenhouse whitefly (outdoors), silverleaf whitefly, sweetpotato whitefly, thrips (suppression only)

Primary Production States: Peppers (Florida, New Mexico, and California) and Tomatoes (Florida and California)

Registered Alternatives: Registered alternatives for the labeled pests are presented in Table 2.

Registrant's Justification: The efficacy of registered alternatives for target pest control in fruiting vegetables was reviewed by the registrant and the benefits claimed by the registrant are:

1. Aphids - Heavy aphid infestations may cause wilting of tomato, but damage does not usually result in yield loss. Of greater significance, however, is that aphids vector tomato diseases such as alfalfa mosaic and tomato yellow top.
2. Whitefly - Whiteflies damage fruiting vegetables, tomatoes in particular, by sucking plant juices from the undersides of leaves causing them to turn yellow and die. The honeydew excreted from feeding activity glazes the plant surfaces and permits development of sooty mold on the surface. The fungus often retards growth and reduces the market value of the fruit. More importantly, whiteflies vector destructive Gemini viruses such as Tomato mottle and Tomato yellow leaf curl virus, which can and have resulted in total crop failure.
3. Aphids and whiteflies have developed resistance to a number of insecticides, including carbamates, neonicotinoids, organophosphates, and pyrethroids. Importantly for whiteflies, insecticide efficacy varies against adult and immature stages. More insecticide options are needed to continue to maintain viable insecticide options to integrate in a comprehensive insecticide resistance management (IRM) program and to extend the functional life of all insecticides.
4. Sulfoxaflor would provide an excellent rotation partner because it is highly effective against aphids and whiteflies and offers a novel mode of action to manage resistance development.
5. Sulfoxaflor provided control of all aphid species greater than or equal to control provided by acetamiprid, imidacloprid, and spirotetramat applied at normal use rates.
6. Sulfoxaflor provides whitefly control equivalent to pyriproxyfen+spirotetramat, imidacloprid, and dinotefuran.

BEAD's Response: Despite the numerous options potentially available, many producers are dependent on insecticides for suppression of aphids (Green peach and Potato) and whiteflies (Greenhouse, Silverleaf, and Sweet potato). BEAD agrees that while aphid feeding does not result in substantial crop losses, they are potential vectors of viral diseases. BEAD also agrees that whitefly control is necessary to prevent vectoring of viruses which can result in complete crop loss.

1. Aphids - Chemical control is advised for both green peach and potato aphid when action thresholds of 3-4 aphids per terminal three leaflets or 50% of leaves are infested (Webb et.al., 2010). Early in the season, aphid infestations are often spotty, and if such plants or areas are treated in a timely manner, great damage can be prevented later in the season (University of Florida, 2005).

a. Potato aphid - The potato aphid is primarily a pest in the Northeast and is generally the easiest to control. Effective insecticide active ingredients include: organophosphates such as acephate and dimethoate; carbamates such as oxamyl and methomyl; pyrethroids; neonicotinoids such as imidacloprid, thiamethoxam, dinotefuran, and acetamiprid; and several novel homopteran-specific and IPM-friendly insecticides such as pymetrozine, spirotetramat and flonicamid. (VCE 2009)
b. Green peach aphid -In some cases, use of insecticides for other, more damaging insects sometimes leads to outbreaks of green peach aphid. Inadvertent destruction of beneficial insects is purported to explain this phenomenon, but aphid resistance to some types of insecticide may also be involved. In addition, Cutler et. al. (2009) determined that sublethal exposure to imidacloprid and azadirachtin can induce hormetic responses, increased reproduction, in green leaf aphid. Application of insecticides rarely is effective in managing the viruses transmitted by aphids, rather insecticides simply slow the spread of disease.

2. Whiteflies - Chemical control of whiteflies in tomato and pepper production is advised when scouting determines 0.5 pupae or nymphs per leaflet or 10 adults per plant (0-3 true leaves) or 1 adult per leaflet (over 3 true leaves) (Webb et.al., 2012). Thresholds have not yet been established for greenhouse whitefly. Failure to control high populations of whiteflies can result in stunting, defoliation, and reduced (Florida IPM, 2012) yields. Drenches of systemic neonicotinoid insecticides such as imidacloprid, thiamethoxam, and dinotefuran before and immediately following transplanting provide early season control that is essential for most tomato production (Florida IPM, 2012). Neonicotinoid drenches provide protection for 6-8 weeks. It is important to alternate different modes of action and not use neonicotinoid insecticides back to back to prevent development of resistant populations (Florida IPM, 2012). While systemic neonicotinoids, primarily imidacloprid, currently provide the bulk of early season control of both whiteflies and aphids and can provide late season control as foliar applications, their continued use after the initial a-planting application is discouraged (Florida IPM, 2012). It is recommended that alternative insecticides be used when the initial at-plant neonicotinoid applications loose effectiveness to prevent development of resistant populations and thereby maintain the effectiveness of the systemic neonicotinoids. While numerous alternative insecticides can provide mid-season control of aphid and whitefly nymphs, endosulfan has been primarily recommended for late season adult whitefly control (Atwood and Rim, 2009). However, endosulfan will no longer be available for use on fruiting vegetables in Florida after December 31, 2014 and in other states after July 15, 2015 (EPA, 2010). Sulfoxaflor could serve as a replacement for the loss of endosulfan for control of mid-season whitefly, particularly in relation to its lack of cross-resistance to neonicotinoid insecticides.
3. Green peach aphid exhibits a striking capacity for rapid adaptation to insecticides, developing resistance to more active compounds than any other known insect (Vasquez, 1995), Six distinct insecticide resistance mechanisms mediating different levels of insensitivity, have been described for the species: (i) Modified acetylcholinesterase (MACE), which confers resistance to organophosphates and carbamate insecticides, (ii) kdr, kinase insert domain receptor), and super kdr mutations in a voltage-gated sodium channel, which is the target of pyrethroids and organochlorines, (iii) the mutation of the

GABA receptor, rdl, which is target of organochlorines of the cyclodiene type, (iv) the recently described mutation of a key residue in the loop D region of a nAChR b1 subunit, (v) the overproduction of esterases E4 or FE4 confers resistance to organophosphates, pyrethroids and to a lesser extent carbamates, and (vi) the recently described over-production of a cytochrome P450 confers resistance to neonicotinoids (Silva et. al. 2012).

4. As shown in Table 2, no insecticides other than neonicotinoids are rated as providing excellent control of either aphids or whiteflies on fruiting vegetables. BEAD agrees that sulfoxaflor has a novel mode of action, with no cross-resistance to neonicotinoids, which could be effective against aphids and whiteflies and also maintain the viability of currently registered insecticides when used in a rotational insecticide resistance management (IRM) program. The lack of cross-resistance would make sulfoxaflor a useful alternative in programs such as Florida tomato production which currently limit highly effective neonicotinoids to either at-plant application or mid- to late-season foliar application to manage neonicotinoid pesticide resistance.
5. While the registrant does provide studies showing the effectiveness of sulfoxaflor against aphid pests on vegetables, the registrant failed to provide data specific for fruiting vegetables. BEAD cannot fully assess the efficacy of sulfoxaflor for this crop group based on the data provided. However, based on studies conducted on other crop groups and identical pests, BEAD has no reason to believe that sulfoxaflor would not be equally effective against aphids on fruiting vegetables.
6. The registrant does provide studies, on tomatoes, that indicate sulfoxaflor can provide effective control of whiteflies on fruiting vegetables. However, of the insecticides used in their comparison tests, only imidacloprid and spirotetramat are currently used on greater than 5% of total acreage (Table 1). In addition, imidacloprid is primarily used as an at-plant application. Therefore, it is not possible for BEAD to conclude that sulfoxaflor will be equally efficacious as the currently used foliar insecticides for whitefly control in fruiting vegetables. However, due to the lack of cross-resistance with neonicotinoids and the exhibited effectiveness of foliar imidacloprid application, sulfoxaflor should be an effective alternative for use against mid- and late-season whitefly populations.

Table 2. Market leader insecticides for pest control on fruiting vegetables.

Pest[1]	Insecticide[2]	Crop Acres Treated (%)[3,4,5,5]	Efficacy Rating for Representative Crops[6]							
			Tomato				Pepper			
			CA[7,8,9,10]	SC GA[11]	VA NC DE[12,13]	FL[14,15]	CA[16,17,18] and NM[19]	DE MD NJ[20]	OH[21]	GA SC[22]
Aphids (Green peach and Potato)	Azadirachtin	5.8	-	-		R	P			
	Bifenthrin	6.2	-	-		R				
	Dimethoate	17.6	G	-	R	R	P-F	F	G	
	Imidacloprid	21.5	G	E	R	R	G-E	G	G	E
	Methomyl	7.9	G	-		R	F-G	F	G	
	Thiamethoxam	5.8	-	-	R	R	G-E	G	G	
Whitefly (Greenhouse, Silverleaf, and Sweet potato)	Azadirachtin	11.8	-			P	P			
	Bifenthrin	11.0	-	F-G		P				F-G
	Chlorantraniliprole	11.0	-							
	Imidacloprid	19.0	E	G-E	R	F-E	G-E		G	F-E
	Oxamyl	6.0	F	F-G		P-F				F-G
	Spirotetramat	6.4	-							

1 Plant bugs were not included as proprietary data indicates no insecticide usage against this pest. Does not include pests where control is limited to suppression (thrips).
2 Only includes alternatives which account for greater than 5 percent of treated acres
3 Does not reflect total crop treated. Based only on the crop acres treated for the specific pest
4 Adjusted to reflect cancellation of endosulfan
5 USEPA. 2012. Proprietary data for 2009 - 2011
6 Rating Scale: E=Excellent, G=Good, F=Fair, P=Poor, R=Recommended but no comparative efficacy ranking
7 USDA. 2003a. Pest Management Strategic Plan California Fresh Market Tomato Production.
8 UC IPM. 2008a. UC Pest Management Guidelines – Tomato – Green Peach and Other Early Season Aphids.
9 UC IPM. 2008b. UC Pest Management Guidelines – Tomato – Potato Aphid.
10 UC IPM. 2008c. UC Pest Management Guidelines – Tomato – Whiteflies.
11 USDA. 2007a. Pest Management Strategic Plan for Tomato in Georgia and South Carolina.
12 USDA. 2006a. Pest Management Strategic Plan for Tomato in Virginia, North Carolina, and Delaware.
13 VCE. 2009. Potato Aphids on Tomatoes. Virginia Cooperative Extension.
14 Webb, SE, PA Stansly, DJ Schuster and JE Funderburk. 2010. Insect Management for Tomatoes, Peppers, and Eggplant.
15 Schuster, DJ, PA Stansly, JE Polston, P Gilreath and E McAvoy. 2007. Management of Whiteflies, Whitefly-Vectored Plant Virus, and Insecticide Resistance for Vegetable Production in Southern Florida.
16 USDA. 2004. A Pest Management Strategic Plan for Pepper Production in California.
17 UC IPM. 2009a. UC Pest Management Guidelines – Peppers – Green Leaf Aphid.
18 UC IPM. 2009b. UC Pest Management Guidelines – Peppers – Whiteflies.
19 USDA. 2000. Crop Profile for Peppers (Chile) in New Mexico.
20 USDA. 2008b. Pest Management Strategic Plan for Bell and Non-Bell Peppers in Delaware, Eastern Shore Maryland, and New Jersey.
21 USDA. 2003b. Bell Pepper and Non-Bell Pepper Pest Management Strategic Plan.
22 USDA. 2007b. Pest Management Strategic Plan for Pepper in Georgia and South Carolina.

Cucurbit Vegetables

Limitations for Cucurbit Vegetables: This analysis is limited to insecticide use on watermelons, cucumbers, pumpkins, cantaloupe, and squash. These crops were chosen as they represent most acreage in the cucurbit vegetable crop group.

Pest(s): aphids, silverleaf whitefly, sweet potato whitefly, thrips (suppression only)

Registered Alternatives: Registered alternatives for the labeled pests are presented in Table 3.

Registrant's Justification: The registrant did not provide either a justification or benefit assessment specifically for cucurbit vegetables. However, the registrant did submit efficacy studies supporting the efficacy of sulfoxaflor on cucurbit crops.

BEAD's Response:

1. BEAD has assessed cucurbit vegetables based on the registrant-provided information on vegetables in general. As the primary pests targeted for control with sulfoxaflor are similar across all vegetable crop groups, aphid and whitefly, BEAD concludes that similar insecticide resistance occurs in cucurbit vegetables as noted for fruiting vegetables. For additional information, refer to the previous discussion of fruiting vegetables.
2. As shown in Table 3, and as determined for fruiting vegetables, the only market leader alternative insecticide which is rated as providing excellent control of aphid is imidacloprid. The only current market leader insecticides which are rated as providing excellent control of whitefly are imidacloprid and pymetrozine. BEAD agrees that sulfoxaflor has a novel mode of action, with no cross-resistance to neonicotinoids, which could be effective against aphids and whiteflies and also maintain the viability of currently registered insecticides when used in a rotational insecticide resistance management (IRM) program. The lack of cross-resistance would make sulfoxaflor a useful alternative in cucurbit production programs which currently limit highly effective neonicotinoids to either at-plant application or mid- to late-season foliar application to manage neonicotinoid pesticide resistance.
3. The registrant submitted three studies for sulfoxaflor on cantaloupe and one for summer squash. Comparison of imidacloprid and sulfoxaflor on summer squash to control cotton aphid indicates that sulfoxaflor is equivalent to imidacloprid at the two low application rates (15 and 25 g ai/ha) and superior to imidacloprid at the highest application rate (50 g ai/ha). The three efficacy studies for whitefly control on cantaloupe determined that sulfoxaflor provides control equivalent to both acetamiprid and spiromesifen.
4. Although the registrant did not provide a justification and benefit assessment for sulfoxaflor use on cucurbit vegetables, based on the field efficacy studies and the target pests, BEAD concludes that sulfoxaflor would provide an additional insecticide capable of providing excellent control of both aphids and whiteflies on cucurbits.

Table 3. Market leader insecticides for pest control on cucurbit vegetables.

Pest[1]	Insecticide[2]	Crop Acres Treated (%)[3,4,5]	Insecticide Efficacy[6]					
			FL water-Melon[7]	DE, MD, NJ, NC Water-Melon[8]	DE, MD pickling cucumber[9]	TN cucurbit[10]	CA melon[11]	IL, IN, IA, MI Pumpkin[12]
Aphids (Green peach and Melon)	Azadirachtin	11.8	F				P	P-F
	Bifenthrin	11.0	P	P-F		G	G	G
	Chlorantraniliprole	11.0						
	Imidacloprid	19.0	E	VG	G		E	G
	Oxamyl	6.0		NL-E		F	F	F
	Spirotetramat	6.4						
Whitefly (Silverleaf and Sweet potato)	Bifenthrin	22.8	F				F	F-G
	Chlorantraniliprole	6.0						
	Dinotefuran	15.2						
	Imidacloprid	21.8	E			E	E	N-P
	Pymetrozine	5.5	G			E		G
	Spiromesifen	6.6						

1 Does not include pests where control is limited to suppression (thrips).
2 Only includes alternatives which account for greater than 5 percent of treated acres
3 USEPA. 2012. Proprietary Data for 2009-2011.
4 Does not reflect total crop treated. Based only on the crop acres treated for the specific pest
5 Adjusted to reflect cancellation of endosulfan
6 Rating Scale: E=Excellent, VG= Very Good, G=Good, F=Fair, P=Poor, R=Recommended but no efficacy data, NL=Not labeled for pest, but effective
7 USDA. 2007c. Watermelon Pest Management Strategic Plan (PMSP).
8 USDA. 2008c. Pest Management Strategic Plan for Watermelons in Delaware, Maryland, New Jersey, and North Carolina.
9 USDA. 2005a. Pest Management Strategic Plan for Cucumbers (Pickling) in Delaware and Eastern Shore Maryland.
10 USDA. 2002a. Tennessee's Pest Management Strategic Plan for Cucurbits.
11 USDA. 2003c. Pest Management Strategic Plan Cantaloupe, Honeydew, and Mixed Melon Production in California.
12 USDA. 2005b. Midwest Pest Management Strategic Plan for Processing & Jack-o-Lantern Pumpkins Illinois, Indiana, Iowa and Missouri.

Benefits Assessment for Citrus

Limitations for Citrus: This analysis is limited to available usage data on orange, grapefruit, and lemon. Due to the majority of citrus production occurring in Florida and California, the benefit assessment for aphids, mealybugs, scales are primarily based on usage information for these states. The benefit assessment for psyllid is based on usage data for Texas and Florida.

Pest(s): – aphids, mealybugs, California red scale, citricola scale, citrus psyllid, citrus snow scale, thrips (suppression only)

Registered Alternatives: Registered alternatives for the labeled pests are presented in Table 4.

Registrant's Justification: The efficacy of registered alternatives for target pest control in citrus was reviewed by the registrant and the benefits claimed by the registrant are:

1. Aphids – No justification or benefits were included in the submission package.
2. Mealybugs – Mealybugs extract plant sap, reducing tree vigor, and excrete honeydew, which gets on plant surfaces and provides a surface upon which sooty mold grows. If a cluster of mealybugs feeds along a fruit stem, fruit drop can occur. Mealybugs are primarily managed by conserving their natural enemies and reducing ant populations and dust, however, economic populations of mealybugs do occur sporadically and require treatment. Chlorpyrifos is the primary insecticide used to control sporadic outbreaks of mealybugs on citrus.
3. Psyllid – Asian citrus psyllid was first observed in Florida in 1998. Once established, this exotic insect has become the most important insect pest of Florida citrus due to the presence of citrus greening disease, which is spread by the psyllid. The Asian citrus psyllid was first detected in California in 2008, but, fortunately, has not yet brought citrus greening disease to California. The California Department of Food and Agriculture has issued quarantines in several counties in an attempt to eradicate the pest before it becomes permanently established. Recommended insecticides for Asian citrus psyllid include chlorpyrifos, dimethoate, fenpropathrin, imidacloprid, phosmet, thiamethoxam and zeta-cypermethrin. Spirotetramat is also registered for use in Florida and Texas but is no longer registered for use in California. All insecticides currently used to control Asian citrus psyllid on bearing trees are broad-spectrum foliar insecticides applied to control adult psyllids prior to the presence of new flush of foliage growth. There are currently no effective insecticides to control juvenile psyllids. Control of overwintering adult psyllid populations is necessary to reduce populations on spring flushes. Early season control is necessary to suppress populations and reduce the need for psyllid control during bloom when most insecticides cannot be used for psyllid control due to bee toxicity.
4. Scale – California red scale, an armored scale, is distributed throughout the citrus-growing regions of California except in the Coachella Valley where they are under an eradication program. Citricola scale, a soft scale, can be a serious pest of citrus in the San Joaquin Valley. California red scale attacks all aerial parts of the tree by sucking on plant tissues. Heavily infested fruit may be downgraded in the packinghouse and, if populations are high, serious damage can occur to trees (leaf yellowing and drop, dieback of twigs and limbs, and occasional death of the tree). Tree damage is most likely to occur in late summer and early fall when scale populations are highest and moisture stress on the tree is greatest. Citricola scale may reduce tree vigor, kill twigs, and reduce flowering and fruit set when occurring in high infestations. Citricola scale feeding results in excretion of honeydew and accumulation on leaves and fruit. Sooty mold grows on honeydew and interferes with photosynthesis in leaves and causes fruit to be downgraded in quality during packing. Oil is the most selective pesticide for scale control but only suppresses populations and requires frequent reapplication. IGRs, such as pyriproxyfen and buprofezin, are safe to most beneficial insects but are toxic to the beneficial vedalia beetle (a species of lady beetle) which is needed to control cottony cushion scale. Furthermore, observations indicate that red scale may be developing resistance to pyriproxyfen. Spirotetramat is safe to beneficial insects and vedalia beetles but cannot be used in California. Organophosphate and carbamate insecticides are broad spectrum and toxic to most natural enemies. In addition, a number of populations of red scale and citricola scale are now resistant to either organophosphate and/or carbamate insecticides.

Neonicotinoids can suppress scale but are toxic to natural enemies and disrupt biological control of cottony cushion scale.

5. Sulfoxaflor is highly effective against the target pests, including resistant populations, and offers acceptable and only short-term impact on natural enemy populations. Sulfoxaflor would replace a significant portion of acreage currently treated with chlorpyrifos.

BEAD's Response: The percentage of total citrus acreage treated nationally for mealybug is 11%, for scale -77.8%, and for aphids - 14.7%) (based on data for orange, grapefruit, and lemon production in Florda, California, Texas and Arizona). The percentage of total acreage treated for psyllid is 100% (based on data for Florida and Texas) (USEPA, 2012).

1. Aphids are primarily pests of citrus in California and Florida. Aphids are generally not a problem on citrus except on young trees because their populations decline when the foliage hardens off. Natural enemies normally control aphid populations, and a spray is rarely warranted. The percentage of total acres treated for aphids in California and Florida is 13.3% and 15.4%, respectively. Populations of cotton aphids in the San Joaquin Valley have been shown to have resistance to organophosphate, carbamate, and pyrethroid insecticides (UC IPM 2008d). In addition, a study by Cutler et. al. (2009) determined that sublethal exposure to imidacloprid and azadirachtin can induce hormetic responses in aphids (e.g. increase in reproduction). BEAD concludes that sulfoxaflor would be most likely to replace either imidacloprid or thiamethoxam for aphid control in citrus. In addition, due to the lack of cross-resistance with neonicotinoids, sulfoxaflor would not only add an additional control option but would provide an alternative to prevent resistance development to the currently used neonicotinoids.
2. Mealybug can exhibit heavy densities in greenhouses but generally are not a problem in citrus production. Mealybugs are primarily managed by conserving their natural enemies and reducing ant populations and dust problems. Treatment is rarely required. The percentage of total acreage treated for mealybug in citrus production in Arizona, California, Florida and Texas is 0.1%, 5.2%, 3.3%, and 2.3%, respectively. In two studies submitted by the registrant, sulfoxaflor performed equal to chlorpyrifos and pyriproxyfen. As chlorpyrifos is the current market leader insecticide to control mealybug in citrus, sulfoxaflor does have the potential to effectively displace/reduce the amount of chlorpyrifos currently used to control mealybug in those rare cases when it is used. It also has the potential to at the least provide an alternative to manage mealybug and minimize potential insect resistance to chlorpyrifos.
3. Psyllids are currently important pests in Florida and Texas citrus with 100% of acres treated to prevent citrus greening disease. In contrast, due to the absence of citrus greening disease, only 2% of California citrus acreage is treated to control psyllids. Currently, treatment in California is limited to prevention of spread of Asian citrus psyllid from the quarantine zone. However, the low percent of acres treated in California is dependent upon the effectiveness of the California quarantine program. Overall, with the exception of chlorpyrifos, psyllid resistance to most insecticides is considered low at this time (Boina et.al. 2009). In Florida, broad-spectrum foliar sprays are most effective when used to control adult psyllids prior to the presence of new flush. Once psyllids begin reproducing on new flush, it becomes increasingly difficult to gain control of rapidly increasing populations. Psyllid management programs should begin by first

targeting overwintering adult psyllids during the winter months when the trees are not producing flush (Rogers et.al., 2012). By eliminating these overwintering adults, psyllid populations will be greatly reduced on the following spring flushes. Targeting psyllids early in the year should provide enough suppression in psyllid populations to reduce the need for psyllid sprays during bloom (Rogers et.al., 2012). In 2 field trials submitted in support of the registration, sulfoxaflor performed equal to chlorpyrifos. In addition, sulfoxaflor provided equal length of psyllid control to the market leader insecticides for adults (25-31 days) but far exceeded all but zeta-cypermethrin for control of nymphs (up to 40 days) when compared to the untreated check (Stansley et.al., 2012). While BEAD concludes that sulfoxaflor is effective for psyllid control, based on the number of effective alternatives, BEAD believes that sulfoxaflor will most likely only provide an additional insecticidal tool.

4. Scale insects are predominantly pests in California with 85.7% of total citrus acreage receiving insecticide application. In contrast, only 1.3% of the total citrus acreage is treated in Florida and 7.6% in Texas. In Florida, scale insects are primarily under biological control and oversprays of pesticides are not recommended (Fasulo and Brooks, 2010). In the San Joaquin Valley of California, a number of populations of armored scale have been found to be resistant to the organophosphates chlorpyrifos (Lorsban) and methidathion (Supracide) and to the carbamate carbaryl (Sevin). Scales have not developed resistance to oil sprays or insect growth regulators (buprofezin - Applaud), but observations indicate that resistance to pyriproxyfen (Esteem) may be developing (UC IPM 2009c). A number of populations of citricola scale have been found to be resistant to the organophosphate chlorpyrifos (Lorsban). Thus, low rates of this insecticide would be ineffective and high rates only suppress citricola scale for a single year (UC IPM 2009d). Sulfoxaflor performed equal to chlorpyrifos and pyriproxyfen in 3 field tests included in the submission package. BEAD concludes that sulfoxaflor can provide effective control of scales in citrus and could potentially reduce current dependence on chlorpyrifos.
5. BEAD agrees with the registrant that sulfoxaflor will be useful to control aphids, scale, psyllid, and mealybugs in citrus production.

Table 4. Market leader insecticides for pest control on citrus.

Pest[1]	Insecticide[2]	Crop Acres Treated (%)[3,4,5]	Strength[6,7,8,9,10,11,12,13]	Weakness[6,7,8,9,10,11,12,13]
Aphids	Abamectin	11.2		
	Acetamiprid	9.3		
	Chlorpyrifos	8.6	Broad spectrum	Cotton aphids in the San Joaquin Valley have shown resistance to organophosphate, carbamate, and pyrethroid insecticides. May increase populations of spider mites.
	Imidacloprid	19.1		Limit on use during bloom, disruptive to natural enemies. Should be applied prior to or at onset of pest population.
	Petroleum oil	17.0	Selective, low impact on beneficials	Requires reapplication, serious phytotoxicity to green lemons, toxic to predatory mites.
	Thiamethoxam	20.1		Cannot be applied during bloom
Mealybugs	Chlorpyrifos	45.8	Broad spectrum	May increase spider mite populations.
	Imidacloprid	17.1		Limit on use during bloom, disruptive to natural enemies
	Petroleum oil	22.0	Selective, short impact on beneficials	Requires reapplication, phytotoxic to green lemons, toxic to predatory mites
	Spirotetramat	11.3	Selective, No impact on vedalia beetles for control of cottony cushion scale	Not registered for use in CA
Psyllid (Asian citrus)	Abamectin	12.9		
	Dimethoate	6.0	Very effective against adult psyllids	Only provide 4-6 weeks control. Very toxic to natural enemies.
	Fenpropathrin	7.1	Very effective against adult psyllids.	Only provide 4-6 weeks control. Very toxic to natural enemies.
	Imidacloprid	11.9	85% effective against nymphs.	Limit on use during bloom due to bee toxicity. Foliar treatment is more disruptive to natural enemies than systemic treatment.
	Petroleum oil	16.6	Effective against adult psyllids	No more than 2 weeks protection, phytotoxic to green lemons.
	Zeta-cypermethrin	16.6	Very effective against adult psyllids.	Only provide 4-6 weeks control. Very toxic to natural enemies.
Scale (Citricola and California red)	Chlorpyrifos	26.3	Selective, many natural enemies have developed resistance and short persistence	Some populations have developed resistance. May increase spider mite populations.
	Petroleum oil	39.0	Relatively non-toxic to natural enemies because of brief residual activity	Temperature must be less than 95 degrees. Only reduces numbers and may require reapplication 2 times per year. Recommended to be applied with carbaryl. Toxic to predatory mites.
	Pyriproxyfen	14.3	Safe for parasitic wasps	Toxic to vedalia beetles needed for control of cottony cushion scale. Observations indicate that resistance may be developing. Not effective for adults

1 Does not include pests where control is limited to suppression.
2 Only includes alternatives which account for greater than 5 percent of treated acres
3 Does not reflect total crop treated. Based only on the crop acres treated for the specific pest
4 Adjusted to reflect cancellation of endosulfan
5 USEPA. 2012. Proprietary Data for 2009-2011.

6 UC IPM. 2008d. UC Pest Management Guidelines – Citrus – Aphids.
7 UC IPM. 2009c. UC Pest Management Guidelines – Citrus – California Red Scale and Yellow Scale.
8 UC IPM. 2009d. UC Pest Management Guidelines – Citrus – Citricola Scale.
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10 UC IPM. 2009b. UC Pest Management Guidelines – Peppers – Whiteflies.
11 USDA. 2009. Pest Management Strategic Plan for Citrus Production in California.
12 USDA. 2003e. A Texas Citrus Pest Management Strategy.
13 Browning et al. 2012. 2012 Florida Citrus Pest Management Guide: Soft-Bodied Insects Attacking Foliage and Fruit

Benefits Assessment for Cotton

Limitations: This analysis is primarily focused on tarnished plant bugs in the mid-south production region. BEAD found that an urgent, non-routine situation existed for the use of sulfoxaflor against tarnished plant bug in Mississippi, Louisiana, Arkansas, and Tennessee in 2012.

Pest(s): – cotton aphid, tarnished plant bug, western tarnished plant bug, brown stink bug (suppression only), silverleaf whitefly, southern green stink bug, sweet potato whitefly, thrips (suppression only)

Registered Alternatives: Registered alternatives for the labeled pests are presented in Table 5.

Registrant's Justification: The efficacy of registered alternatives controlling the target pests on cotton was reviewed by the registrant and the benefits claimed by the registrant are:

1. More insecticides are applied for control of plant bugs than control of any other insect pest in cotton. The number of insecticide applications and costs of control have increased.
2. Tarnished plant bugs were estimated to infest 1.3 million acres in Louisiana, Mississippi, Arkansas, and Tennessee, nearly all cotton production acreage in this region. Yield losses due to plant bug were estimated at 79,000 bales (nearly $25 million) and insecticide and application costs were estimated at nearly $44 million in 2009
3. Tarnished plant bug populations express varying levels of resistance to organophosphate, pyrethroid, and carbamate insecticides.
4. Due to boll weevil eradication and the adoption of transgenic Bt cotton, fewer insecticides are being applied which in turn favor development of tarnished plant bugs and western tarnished plant bugs.
5. While control of western tarnished plant bug has been achieved in Arizona using flonicamid, growers cannot rely on a single insecticide for long-term pest management. Similarly, while California has relied on pyrethroids to control western tarnished plant bug, pyrethroids are disruptive to beneficial populations and IPM programs and may flare mites and aphids. In addition, surveys in California indicate that western tarnished plant bugs are developing resistance to pyrethroids with shorter residual control and need for retreatment.
6. With multiple mechanisms of resistance in populations of plant bugs, many of the recommended insecticides no longer provide consistent control, and novel compounds are desperately needed. Sulfoxaflor is highly effective against plant bugs and offers a novel mode of action to manage resistant populations.

BEAD's Response: BEAD conducted a review of an emergency exemption request assessment for the use of sulfoxaflor on mid-south cotton (Louisiana, Mississippi, Tennessee, and Arkansas) to control tarnished plant bug in 2012 (Atwood and Faulkner 2012).

1. *Pest Information* (USDA 2003d): Plant bugs lay their eggs inside tender and succulent cotton stems, making them very difficult to detect in the field. Generally plant bugs will hatch in 10 to 14 days; they will spend 10 to 18 days as nymphs; with five nymphal stages. Tarnished plant bugs overwinter as adults in ground trash near host plants.

   Severe plant bug infestations can develop quickly because bug populations may build on other host plants and then move into cotton. Wild and cultivated plant hosts include most common roadside weeds and cultivated crops such as alfalfa, soybean, vegetables and corn. Plant bugs can move onto cotton from proximate wild host plants or crops when those plants senesce or are mowed or sprayed with herbicides. Growers may be faced with a severe plant bug infestation just days after having relatively clean fields. Infestations occur throughout crop development, but the period from the seedling stage until the second week of flower is when plant bugs are of greatest concern in most mid-south production systems. In recent years, the reduced spray environment fostered by the Boll Weevil Eradication Program and transgenic Bt cotton have been such that plant bug population densities build in July and August to levels that potentially could result in economic damage.

   Plant bugs feed using the process of extra-oral digestion or solid-to-liquid feeding. Their piercing mouthparts penetrate and macerate plant tissues and at the same time delivering chemically macerating digestive enzymes. The resulting concentrated plant slurry is then sucked up by the bug. Feeding sites include fruit and floral tissues and meristematic cells.

   In pre-squaring cotton, the terminal portions of plants are preferred feeding sites. Injury from plant bug feeding at this crop stage can cause loss of apical dominance, which can result in multiple terminals per plant, a condition sometimes referred to as "crazy cotton". Reduced growth following terminal injury of pre-squaring cotton can delay development of squares, crop maturity and reduce yield if optimal growing conditions do not allow for compensatory growth. As the cotton crop develops, squares become important feeding sites.

   Small squares will shed following plant bug feeding, but larger squares typically are more tolerant. The probability of square abscission following tarnished plant bug feeding is a function of anther size. When anthers are hardly visible, the bug feeds on the totality of the floral bud. As the square grows, the anthers reach a large enough size for the bug to feed on the individual pollen sack. When tarnished plant bug feeding is localized on the anthers, shed rarely happens; however, squares with extensive anther damage may shed as bolls. Flowers may be attacked by plant bugs, with feeding resulting in warty growths on flower petals and brown spots on stamens and pistils. Atwood and Faulkner (2012) determined a potential yield loss of 15% per acre in Mississippi cotton directly related to the tarnished plant bug.

2. *Biological/Cultural Control:* Biological alternatives cannot adequately control tarnished plant bug. However, reduced crop damage and insecticide applications against the tarnished plant bug can be achieved through early planting.

3. *Required Number of Insecticide Applications:* Cotton consultant survey data (2007) submitted by Mississippi indicates that 77% of Delta cotton acreage receives greater than 7 insecticide applications per year to control tarnished plant bug with a range of 7 to 16 applications. BEAD proprietary application data for the counties included in the new submission indicates an average insecticide application range of 3.8 to 6.4 for the same counties between 2007 and 2010. However, BEAD believes that state sampling data may be more extensive than that provided by the proprietary database and therefore more indicative of actual insecticide use in Mississippi. Therefore, BEAD believes the average of 8 applications indicated by Mississippi is a more accurate assessment of insecticide use against the tarnished plant bug in the delta region of Mississippi.

4. *Insecticide Resistance:* BEAD review of the two previous submissions in 2011 requesting the use of sulfoxaflor to control tarnished plant bug concluded that sufficient alternatives were available to provide season-long control of tarnished plant bug (7-10 insecticide applications). These insecticides included novaluron, bifenthrin/imidacloprid, beta-cyfluthrin, thiamethoxam/lambda-cyhalothrin, clothianidan (supplemental labeled through 2012), dicrotophos, and acephate. However, the revised applications from Mississippi in 2012 provided additional insight into the extent and magnitude of resistance of the tarnished plant bug to currently registered insecticides.

   Mississippi indicated that synthetic pyrethroids are no longer recommended for tarnished plant bug control. A summary of trials conducted from 2004 to 2010 at the Stoneville, MS Extension Center confirms this conclusion by showing that pyrethroids only provided control in the range of 0 to 47% between 2004 and 2010. In addition, data submitted for 2007 field trials using acephate and bifenthrin (the most active pyrethroid), shows inability to maintain populations below the action threshold level when applied either alone or in combination with acephate. In addition, as co-application of mixtures of neonicotinoid and synthetic pyrethroids has become a primary means to control tarnished plant bugs, application of pyrethroids as an individual application is limited due to seasonal restrictions on total amount applied.

   Additional data in the submission, from laboratory and field studies, verify claims that effectiveness of acephate and dicrotophos has been greatly reduced since 2005. In lab studies, acephate was not able to provide in excess of 48% tarnished plant bug mortality when applied at maximum field rates. Field studies conducted in Stoneville, MS also show decreased activity of acephate and dicrotophos (approximately 39% and 51% reduction in percent control between 2005 and 2010, respectively). Yield losses in the same studies between the same periods were approximately 30% regardless of insecticide used. This data confirms that organophosphates are no longer providing effective control of the tarnished plant bug in Mississippi.

The third primary insecticide class which has been used to control tarnished plant bug is the neonicotinoids. Mississippi indicates that tarnished plant bug control has always been inconsistent with this class of insecticides. However, neonicotinoids are also used to control thrips and cotton aphid prior to the first sprays needed for tarnished plant bugs, so some in-field selection of populations is occurring, as well as limiting the available total active ingredient of these products that can be used later in the season. Some populations of tarnished plant bugs are expressing variation in responses to these products (thiamethoxam, imidacloprid, and acetamiprid) as well. In addition, one population in Mississippi has shown resistance to thiamethoxam, the most active neonicotinoid against tarnished plant bug. While field control failures have not been documented using thiamethoxam, continued reliance on neonicotinoids as the primary tool for controlling tarnished plant bug may expedite resistance to this class of insecticides.

Novaluron is able to control small tarnished plant bug nymphs but is not effective against large nymphs or adults. Due to the rapid development of tarnished plant bugs, this makes application timing critical to target eggs and small nymphs in order to obtain effective control. Due to eggs being laid in plant tissue and not readily visible, proper timing to achieve maximum control of small nymphs is complicated and can be unreliable. In order to be effective, novaluron is best applied in conjunction with an adulticide which further limits the pool of available seasonal insecticide applications.

5. *Conclusion*: BEAD concluded that the situation described in the emergency exemption request was non-routine, urgent, and likely to result in significant economic loss. Season long control of the tarnished plant bug in Mississippi at levels below the economic threshold and which do not result in an economic loss was not deemed achievable with the currently registered insecticides and warranted the request for sulfoxaflor. Furthermore, BEAD concluded that the tarnished plant bug situation was not unique to Mississippi and was applicable to all contiguous cotton producing counties in the Delta region of the United States to also include the states of Arkansas, Tennessee, and Louisiana.

6. Based on the findings of this review, BEAD believes that sulfoxaflor will be an important insecticide for control of insect pests on cotton.

Table 5. Market leader insecticides for pest control on cotton.

Pest[1]	Insecticide[2]	Market Share (%)[3,4,5]	Insecticide Weakness
Cotton aphid	Acephate	18.2	Resistant populations
	Acetamiprid	5.6	Populations expressing resistance
	Aldicarb	7.6	May no longer be available
	Dicrotophos	9.4	Resistant populations
	Imidacloprid	14.0	Populations expressing variation in response
	Thiamethoxam	28.7	Limit to annual total application due to primary use for at plant control of thrips. Insect resistance reported
Southern green stink bug	Bifenthrin	12.3	No recommended due to ineffective control and causes aphid outbreaks
	Zeta-cypermethrin	87.7	No recommended due to ineffective control and causes aphid outbreaks
Tarnished plant bug	Acephate	21.8	Resistant populations
	Bifenthrin	11.2	No recommended due to ineffective control and causes aphid outbreaks
	Dicrotophos	15.4	Resistant populations
	Imidacloprid	12.8	Populations expressing variation in response
	Thiamethoxam	18.2	Limit to annual total application due to primary use for at plant control of thrips. Insect resistance reported.
Whitefly (Silverleaf and Sweet potato)	Acephate	6.3	Resistant populations
	Acetamiprid	22.9	
	Buprofezin	13.6	
	Cyfluthrin	8.2	No recommended due to ineffective control and causes aphid outbreaks
	Dicrotophos	6.0	Resistant populations
	Flonicamid	8.0	
	Pyriproxyfen	10.9	

1 Does not include pests where control is limited to suppression (thrips).
2 Only includes alternatives which account for greater than 5 percent of treated acres
3 Does not reflect total crop treated. Based only on the crop acres treated for the specific pest
4 Adjusted to reflect cancellation of endosulfan
5 USEPA. 2012. Proprietary Data for 2009-2011.

Importance of Bee Pollination

Table 6 provides estimates of the importance of honey bees as pollinators of the crops assessed in this benefit analysis.

Table 6. Importance of honey bees to crop pollination for assessed crops.

Crop Group	Crop	Dependence of Crop On Insect Pollination[1] (%)	Proportion of Pollinators That Are Honey Bees[1] (%)	Percentage Pollinated by Honey Bees[1]	Acres Grown[2]
Cucurbit Vegetable	Cucumber	90	90	81	151,759
	Cantaloupe	80	90	72	84,290
	Honeydew Melon	80	90	72	17,344
	Pumpkin	90	10	9	92,955
	Squash	90	10	9	54,454
	Watermelon	70	90	63	142,359
Citrus	Grapefruit	80	90	72	102,578
	Lemon	20	100	20	66,972
	Lime	30	90	27	1,251
	Orange	30	90	27	785,856
	Tangelo	40	90	36	9,694
	Tangerine	50	90	45	36,965
	Temple	30	90	27	1,211
Cotton	Cotton	20	80	16	10,493,238

1. Morse and Calerone. 2000 The Value of Honey Bees As Pollinators of U.S. Crops in 2000.
2. USDA/NASS. 2009. 2007 Census of Agriculture.

Fruiting Vegetables

The flower structure of fruiting vegetables is such that only the pollen from their own stamens can reach their stigma. These flowers are called self-pollinated. In addition, flowers of fruiting vegetables are not especially attractive to honey bees. Unlike tomatoes, peppers and eggplant may benefit from honey bee pollination with a resulting increase in yield. However, honey bee pollination of these plants is not essential for crop production. Use of sulfoxaflor on fruiting vegetables is not likely to result in exposure to honey bees.

Cucurbit Vegetables

Melon and cucumber flowers are pollinated exclusively by honey bees and other insect pollinators. They are not wind or self-pollinated. Insects are required for pollen transfer because of the large size of the pollen grains, their stickiness, and the way they are released from the anthers. Also, since these plants typically produce only small amounts of pollen, pollinators are needed to efficiently transfer pollen from one flower to the next. While wild bees or distant honey bee colonies may suffice for small melon or cucumber fields, they may be inadequate for the commercial grower whose income depends on substantial yields of high quality fruit (Hodges and Baxendale, 2012).

The individual flowers of cucurbits remain open only for a single day. If they are not pollinated during that time, the flowers abort and drop from the vine. When incomplete pollination occurs, fruit do not develop properly. Because many seeds form within each fruit and each pollen grain is responsible for the development of a single seed, inadequate pollination results in small or misshapen fruit and low yields of marketable fruit.

Cucurbit flowers open shortly after sunrise and remain open until late afternoon or early evening, so each flower is open for only a few hours. The honey bee is the most common and effective cucurbit pollinator. Honey bee activity closely coincides with the period when the flower is open. Honey bees begin to visit flowers an hour or two after sunrise and continue to visit until mid-afternoon. If temperatures are very warm, bee activity may decline about noon (Hodges and Baxendale, 2012).

Researchers have found that it takes at least nine honey bee visits per flower to pollinate cucumbers adequately. Since each bee will visit about 100 flowers per foraging trip, usually at least one strong hive per acre is required. Bees are most efficient if they can forage within 200 yards of the hive. Honey bee colonies should be moved into position near the field about the time the first female flowers are seen. If the bees are moved in too early, they may find other attractive flowering plants in the area and not work the cucurbits. Hives can be removed from melon fields when flowering begins to diminish or when the vines begin to break down. Leave colonies in cucumber fields until a day or so before the last picking. (Hodges and Baxendale, 2012)

Based on this information, BEAD concludes that honey bee pollination is important for the production of cucurbit vegetables, particularly cucumbers and melons. However, based on the phenology of the crop and associated honey bee activity, honey bee exposure to sulfoxaflor can be greatly reduced by restricting applications to late afternoon when honey bees are not likely to be active.

<u>Citrus</u>

The pollination requirements for citrus are complex because of the number of citrus varieties that have been developed. Each variety has its own characteristics and pollination requirements. Recommendations for one variety may not be applicable to another variety.

From a grower's present perspective, information on citrus pollination may seem academic. Most citrus is, fortuitously for growers, superior in nectar production, responsible in good years for a premium, high quality honey crop. Thus, there are always plenty of bees in the groves; whatever pollination is needed is right at hand. And best of all, it's provided free for the producer in exchange for nectar that would otherwise go to waste (Sanford, 2003). The key point is that commercial beekeepers seek out citrus groves for honey production rather than citrus growers seeking commercial bee hives for pollination.

Flowering influences the timing of important and costly operations such as the spring pesticide applications, the placing of beehives for citrus honey production, and probably the employment of labor for harvesting. Although the duration of bloom in individual groves is usually 12 to 20 days, citrus groves on a statewide basis in Florida have a moderate amount of bloom for an average of 41 days, approximately from March 5 to April 15. Bloom may be more than twice as abundant in a year of maximum bloom as compared to a year of minimum bloom (Simanton, 1969).

In summary it may be concluded that honey bees are important in the pollination of citrus, though some varieties benefit more than others. As bees are always present in citrus groves due to their rich nectar resources, pollination in citrus becomes little more than an academic exercise. Major questions, however, remain related to bee distribution in citrus groves and management methods which would optimize their pollinating activities. Nevertheless, based on the periodicity of bloom noted for citrus in Florida, honey bee exposure to sulfoxaflor can be greatly reduced by restricting applications to the non-bloom period.

Cotton (Danka 2005)

Yield of upland cotton may increase by 3-30% following pollination by honey bees. However, honey bees only rarely collect cotton pollen in most regions of the United States and this behavior probably restricts their pollination effectiveness.

Bee Pollination – Conclusion

Overall, honey bees are only essential to the production of cucurbit vegetables. However, this is not to say that honey bee pollination of fruiting vegetables, citrus, and cotton has no benefit. BEAD concludes that due to crop phenology and bee importance to individual crops, sulfoxaflor application should result in little honey bee exposure when restricted to times when flowers are not present or late afternoon sprays with reduced bee activity.

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